# *Designing Surge-Arrester Devices for Transformer GIC Protection*

**Alberto Ramirez Orquin** **Vanessa Ramirez**

**Resilient Grids, LLC**

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# *EMP Facts*

Russian military writings claim to have a super EMP weapon that can generate 200 kV/m*

Congressional Research Service, Clay Wilson, High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments," 2008

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# *EMP Facts*

Research funded by PSERC, DOE, NSF, EPRI, BPA, the State of Illinois DCEO, and ARPA-E*, concludes that: “The two key concerns from a big storm or an HEMP are:

1) Large scale blackout due to voltage collapse, and
2) Permanent transformer damage due to overheating”.

*ARPA-E, stands for Advanced Research Projects Agency-Energy

# *EMP State of the Art*

General consensus: Substantial knowledge-gaps on EMP

Caution call about making optimistic assumptions about equipment resilience

# *New Challenges*

EMP-E3 GIC potentially larger than transformer load or rated current

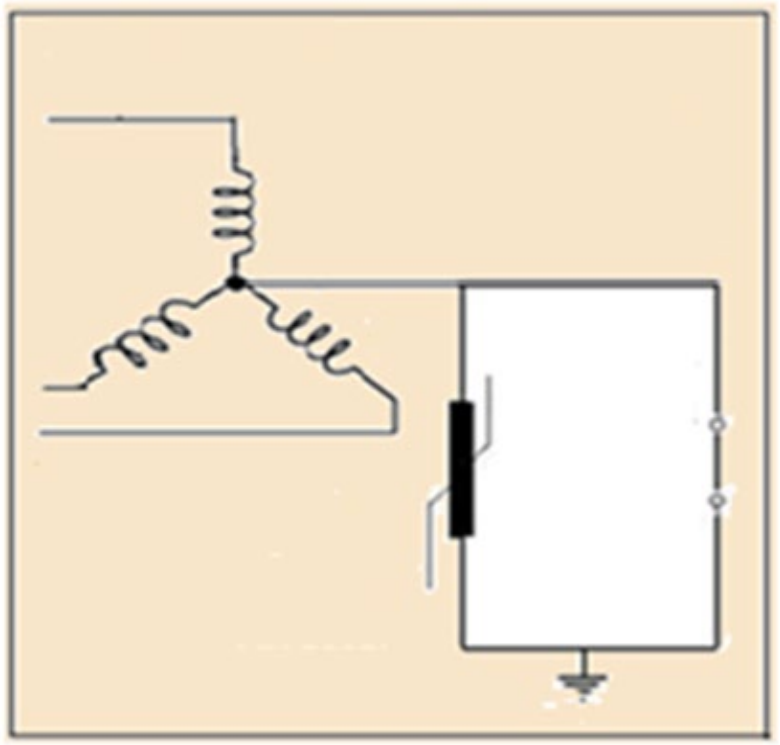
Breakers face non-zero crossing current interruption

Sustained exposure can damage both Breakers and Transformers

# *Worthy Statement*

“ The electric utility industry has taken a different approach: historically, the industry has hardened its individual components, allowing flexibility to install them in virtually any environment. This approach has significantly reduced the overall cost to implement and minimize the cost to rate payers.”

# *Surge Arrester GIC-Blocking Concept*



Surge-Arrester Device

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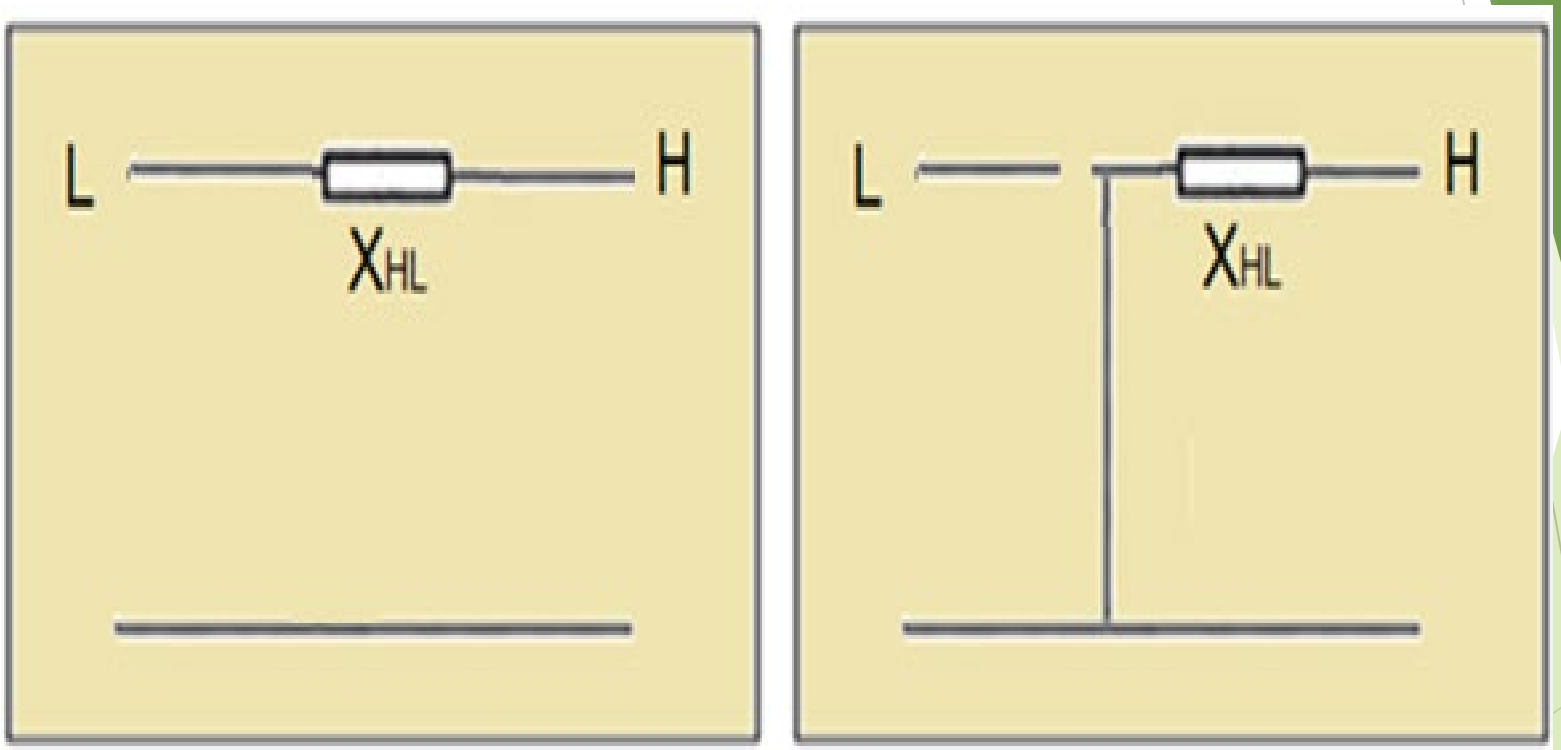
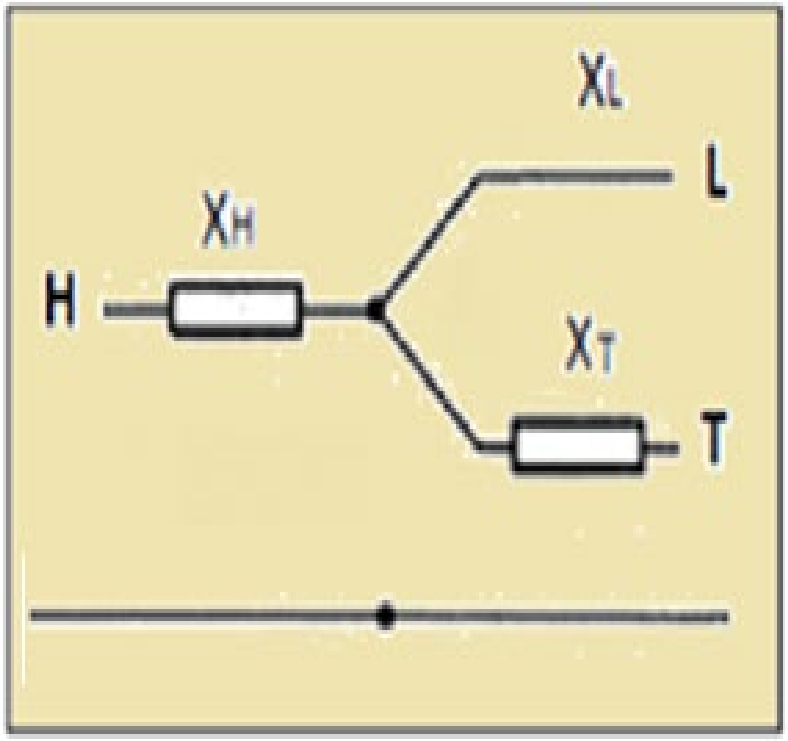
# GSU Transformer



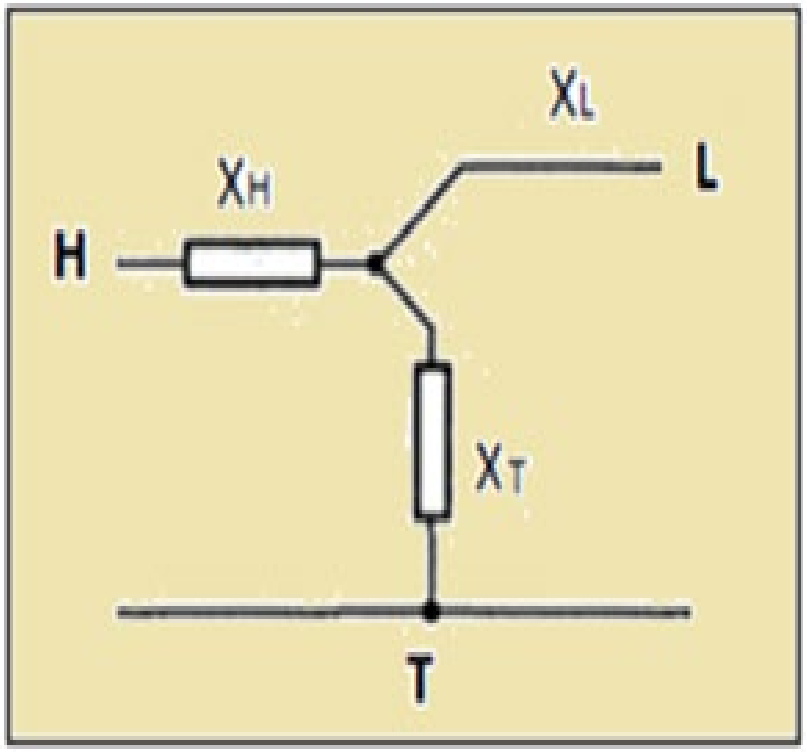

Positive/negative-sequence per-unit equivalent circuit

Zero-sequence per-unit equivalent circuit

# *Three-winding Autotransformer*

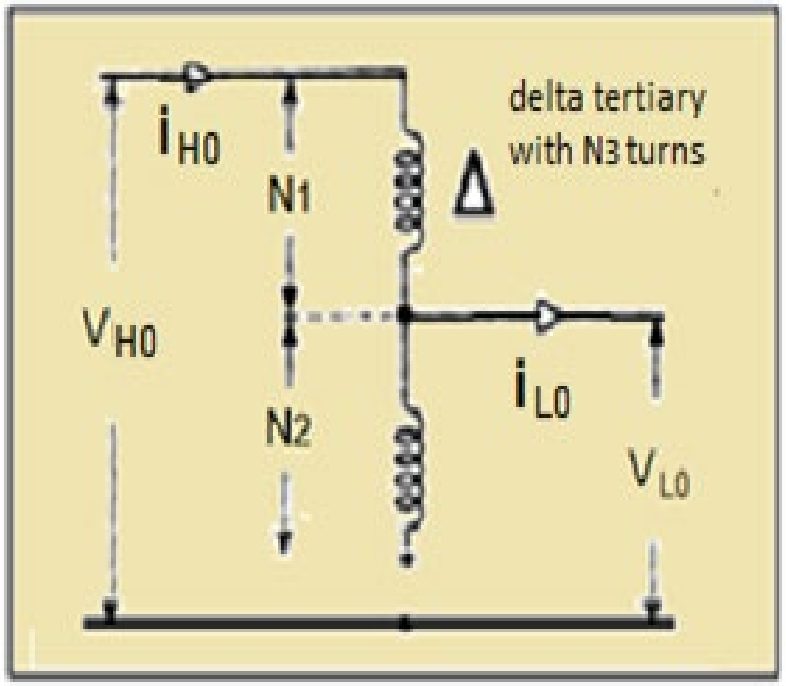



Positive/negative-sequence per-unit equivalent circuit

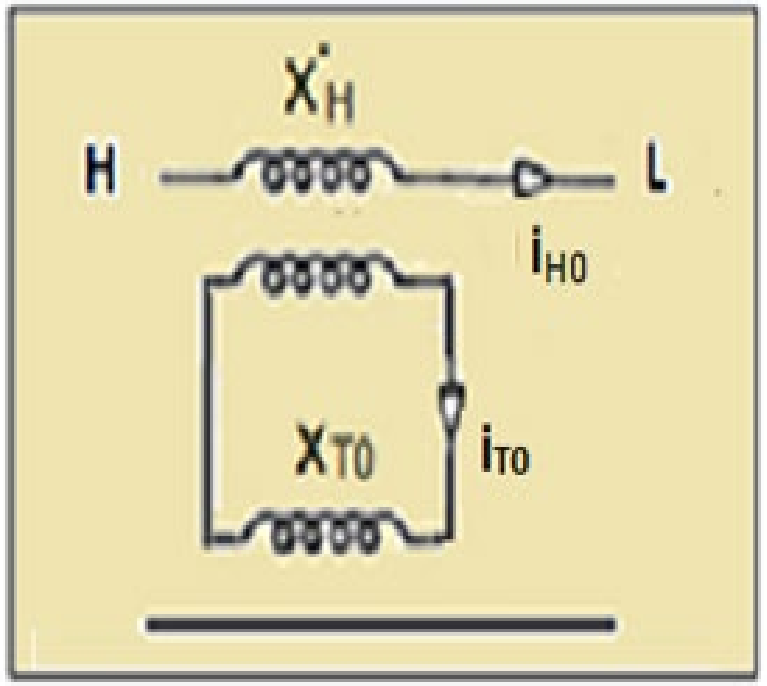



Zero-sequence per-unit equivalent circuit

# *Three-winding Autotransformer equivalent circuit after Surge-Arrester deployment*

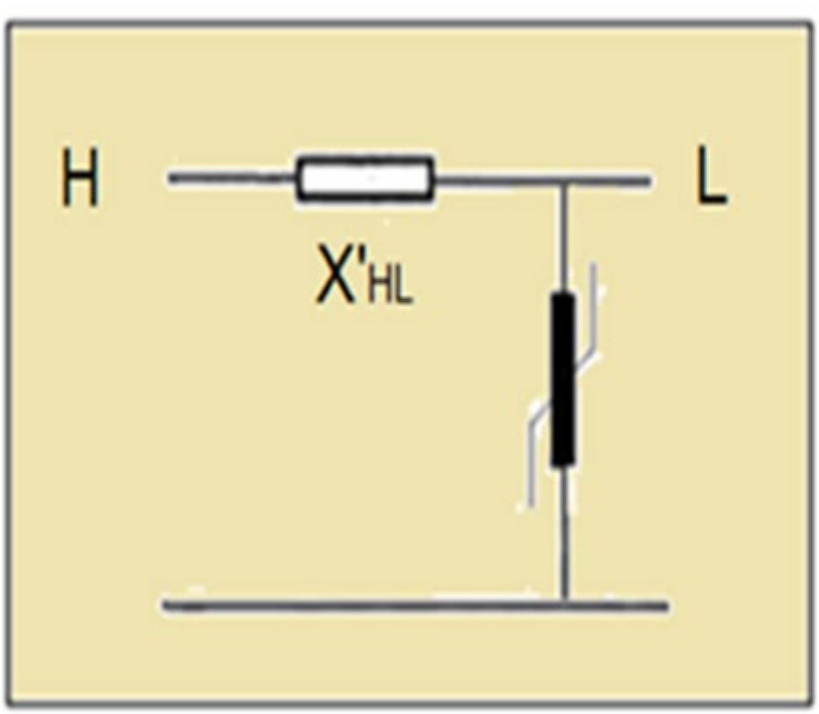



One-line diagram of autotransformer with isolation from neutral to ground: zero-sequence current flow

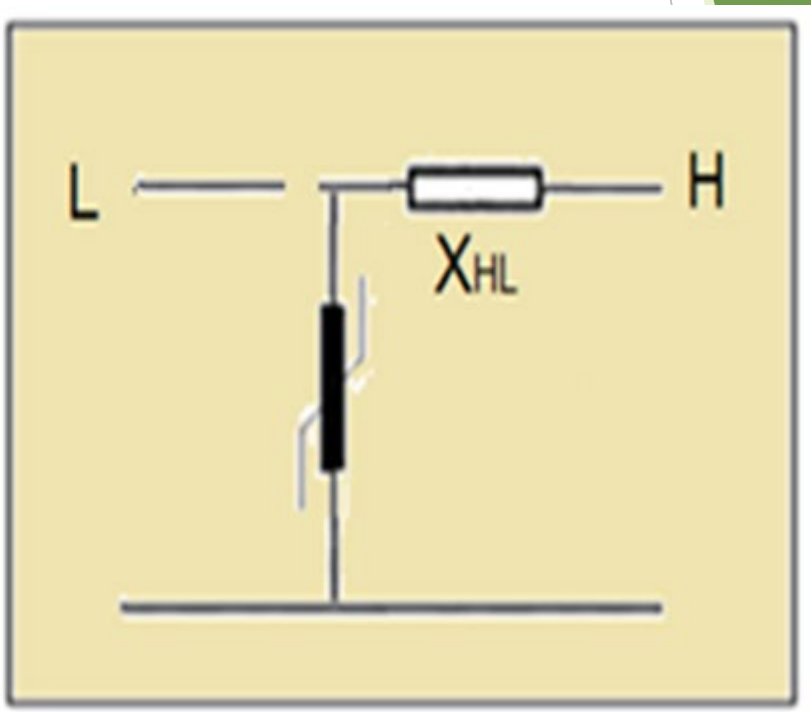



Zero-sequence equivalent circuit of autotransformer with neutral isolated from ground

# *Zero-Sequence Equivalents after Device Deployment*

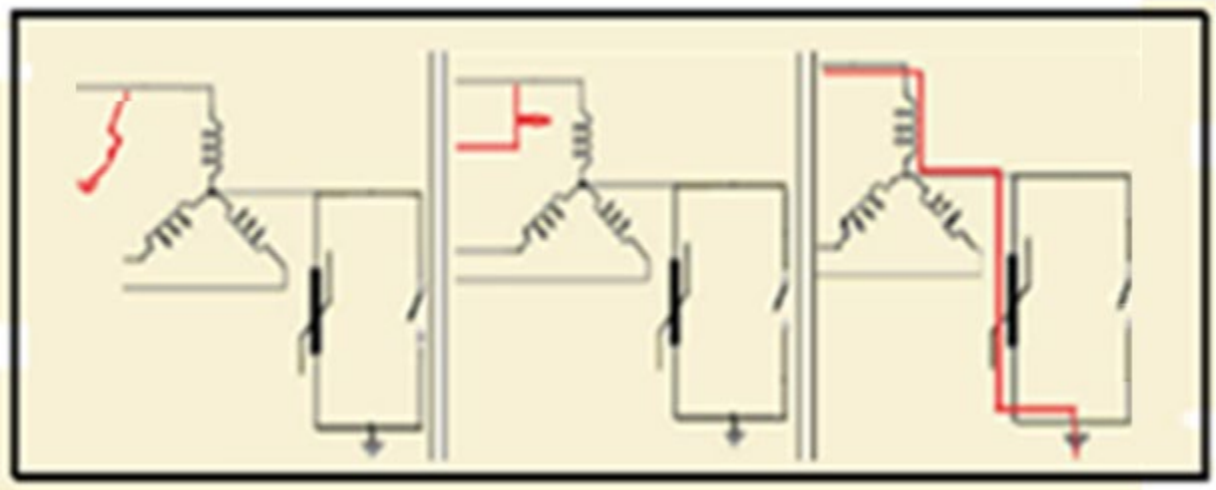



Autotransformer




GSU

# *SLGF sequence of events for a GSU with Surge-Arrester Device Deployed*



a) Arcing ground b) Voltage-zeroing wave surge c) Arrester Short-circuit grounding

# *Alternative Methods to cope with GIC*

Operational Procedures

Stockpile for Transformer Unit Replacement/Modular Components

Blockers based on bulky Components

# *Alternative Methods to cope with GIC*

Remain without Cost/Benefit Evaluation

Evaluation, basic for rate impact as originally required by FERC's Order

# *Conclusions*

## *Regarding Alternative Methods*

Will not address GIC Magnitude Control

Pending Cost-effectiveness/Benefit

Unintended Consequences of Alternative methods not fully studied

# *Conclusions*

Basic design tools presented for the implementation of the GIC Surge-arrester Mitigation Device

# *Conclusions*

## *Device attributes fully examined*

Steady-state performance

Ground-current residuals

Line-Parameter impacts/invariance

Grounding Coefficients

Ground Faults

# *Conclusions*

## *Device attributes fully examined*

Relay Applications (including Close-in faults memory polarization for directionality)

Energy/Power dissipation

Substation Layout

# *Conclusions*

The use of GIC Blocking technology could minimize frequent and onerous GMD-driven, VAR-rationing operational procedures

# Questions?

Thank You

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